IV. "The Coefficient of Viscosity of Air." By Herbert Tomlinson, B.A. Communicated by Professor G. G. Stokes, P.R.S. Received January 6, 1886.

(Abstract.)

The author has had occasion, whilst investigating the internal friction of metals, to determine the coefficient of viscosity of air. The viscosity of air has already engaged the attention of several distinguished experimenters, amongst others, of G. G. Stokes, Meyer, and Clerk Maxwell. The results obtained, however, differ so widely that it was considered necessary to institute fresh researches into the same subject.

The author employed the torsional vibrations of cylinders and spheres, suspended vertically from a horizontal cylindrical bar, and oscillating in a sufficiently unconfined space. The bar was suspended by a rather fine wire of copper or silver attached to its centre, which, after having been previously subjected to a certain preliminary treatment with a view of reducing the internal molecular friction, was set in vibration. The vibrations were performed in a large box, which was rendered sufficiently air-tight to prevent currents of air from vitiating the results. The wire, which was about 97 cm. in length, was suspended in an air-chamber, the double walls of which enclosed between them a layer of water. This air-chamber was in turn surrounded by a second, also provided with double walls which contained sawdust in the space between them. The object of the two air-chambers was to protect the wire as much as possible from small fluctuations of temperature, which last had been found to render the internal friction of the metal very uncertain.

The coefficient of viscosity of air was obtained from observations of the diminution of the amplitude of vibration, produced by the resistance of the air to the oscillating spheres or cylinders attached to the horizontal bar, arrangements having been made so that the vibration-period of the wire should remain the same, whether the cylinders or spheres were hanging to the bar or not. In deducing the value of the coefficient of viscosity from the logarithmic decrement, the author has availed himself of the mathematical investigations of Professor G. G. Stokes.*

Five sets of experiments were made with hollow cylinders and wooden spheres, in the construction and measurement of which considerable care was taken. When the cylinders were used arrange-

* See Professor Stokes's paper "On the Effect of the Internal Friction of Fluids on the Motion of Pendulums," "Trans. Camb. Phil. Soc.," vol. ix, Part II, 1850.

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ments were made to eliminate the effect of the friction of the air on their ends. The following are the results:—

Length in centimetres.	Diameter in centimetres.	Vibration-period in seconds.	Temperature of the air in degrees centigrade.	Coefficient of viscosity of the air in C.G.S. units.
		Cylinders.		
60·875	2·5636	6·8373	12·02	0·00018171
60·885	0·9636	7·0590	14·63	0·00018122
60·875	2·5636	3·0198	11·69	0·00018024
53·175	2·5636	2·9994	10·64	0·00017845
		Spheres.		
	6·364	2·8801	9·35	0·00017820

Maxwell has proved* that the coefficient of viscosity of air is independent of the pressure and directly proportional to the absolute temperature. We can, therefore, calculate from the above data what would be the value of the coefficient of viscosity at 0° C.; and when this is done, in the case of each of the five sets of experiments, we obtain the following values:—

Set of experiments.	Coefficient of viscosity of air at 0° C.
1st	0·00017404
2nd................	0·00017201
3rd	0·00017284
4th	0·00017359
5th	0·00017230

The mean of these numbers is 0·00017296 with a probable error of only 0·14 per cent. The formula for finding μ_t, the coefficient of viscosity of air at the temperature t° C., is therefore—

$$\mu_t = 0\cdot00017296\left(1+\frac{t}{273}\right).$$

The value of the coefficient of viscosity of air at 0° C. given above, though much nearer to that obtained by Maxwell than any which has been got by other observers, nevertheless differs from it by more than 8 per cent. Maxwell experimented with dry air freed from carbonic acid, but it does not seem possible that the small amount of aqueous vapour and carbonic acid present in ordinary air can be credited with a diminution of 8 per cent. in the viscosity; nor can

* "Phil. Trans.," 1866, vol. 156, Part I.

the author explain in any way the difference between his own result and that of Maxwell.

[The method followed by Maxwell is liable to be vitiated to a very sensible degree by small errors of level of the movable disks, especially when they are closest to the fixed disks. The final adjustment is stated to have been that of the fixed disks, and no special precautions seem to have been taken to secure the exact horizontality of the movable disks. By a calculation founded on the equations of motion of a viscous fluid, I find that at the closest distance (about the one-sixth of an inch) at which the fixed and movable disks were set, an error of level of only 1° 8′ would suffice to make the internal friction appear 8 per cent. too high.

In Mr. Tomlinson's reductions no allowance has at present been made for the effect of the rotation of the spheres or cylinders about their own axes, which is not quite insensible, as it would be in the case of a ball pendulum. The introduction of a correction on this account would slightly diminish the values resulting from the experiments, especially in the case of the sphere, where it would come to about 4 per cent.—G. G. S.]

January 21, 1886.

Professor STOKES, D.C.L., President, in the Chair.

The presents received were laid on the table, and thanks ordered for them.

The following Papers were read:—

I. "Family Likeness in Stature." By FRANCIS GALTON, F.R.S. With an Appendix by J. D. HAMILTON DICKSON, Fellow and Tutor of St. Peter's College, Cambridge. Received January 1, 1886.

I propose to express by formulæ the relation that subsists between the statures of specified men and those of their kinsmen in any given degree, and to explain the processes through which family peculiarities of stature gradually diminish, until in every remote degree of kinship the group of kinsmen becomes undistinguishable from a group selected out of the general population at random. I shall determine the constants in my formulæ referring to kinship with a useful